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Ventilated rainscreen cladding: Measurements of cavity air velocities, estimation of air change rates and evaluation of driving forces

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A R T I C L E I N F O

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A B S T R A C T

To analyse the moisture performance of wall systems with a ventilated rainscreen cladding, the air change rate per hour (ACH) is required. However, the average ACH and its variation depend on many factors. This study focuses on performing field measurements of air velocities and temperatures in south oriented wall cavities characterised by either vertical wooden battens or horizontal vented metal battens. A physical cavity airflow model together with laboratory test of loss factors were used to analyse the data and interpret the results.

With vertical battens, findings estimated the average ACH during a measurement period to be 230–310 ACH. In the cavities with horizontal battens, the ACH was 60–70% lower. The daily variations were considerable and hours with solar radiation and clear skies resulted in ACH that exceeded the average values 2–3 times. In contrast to airflow induced by thermal buoyancy, wind-induced airflow was irregular with frequent changes in both velocity and direction. This pattern was observed independent of the angle between the wind and the cladding. The frequent changes in flow direction significantly reduced the efficiency of wind-driven airflow to create air exchange. The wind-induced airflow in wall cavities with a pronounced non-linear relationship between the driving force and the air velocity is suppressed in the presence of buoyancy. For rainscreen claddings exposed to many hours of solar radiation, this effect increases the possibility of accurate estimations of ACH.

1. Introduction

During the last few years, Sweden has experienced severe problems with moisture intrusion in exterior walls with wood framing and face-sealed ETICS (called EIFS in North America). These moisture problems have not only been limited to thin, organic renderings applied on expanded polystyrene, but also include 20–25 mm thick mineral renderings applied on high-density mineral wool insulation. A detailed description of typical constructional build-ups and causes of wetting and deterioration of material layers inside these undrained and unventilated wall systems is given in a comprehensive national survey that was presented in 2009 [1]. In addition, there are numerous reports from both Europe and North America that discuss problems and solutions when ETICS is used on wood frame structures, which shows that failures with ETICS are not unique to Sweden (e.g. [2] and [3]).

In the light of the drawbacks with ETICS, the building industry is seeking for more moisture safe designs of rendered façades on wood frame structures. As a result of this, there is an ongoing transfer from ETICS to technical solutions that utilize the rainscreen principle. In the latter case, render is not applied to thermal insulation but to a carrier board, which is separated from the wall core by battens to create a drained and ventilated cavity. The principle material layers of such a façade cladding and three possible batten configurations are shown in Fig. 1.

Each of the systems illustrated in Fig. 1 has some advantages and disadvantages. Configuration 1a) is the most straightforward solution to create a cavity. However, the boards (of typical dimension 1200 mm × 800–900 mm) are costly so there are strong incentives to minimize the waste of this material by adaptation of the batten spacing to the best fit of the size of the boards. This is normally not achievable with configuration 1a) as the placement of battens must be consistent with positions of studs in the wall core. With configuration 1b) this particular problem is solved, but a significant disadvantage of this approach is an unwanted increase of the total wall depth. For these reasons, configuration 1c) with horizontal and vented metal battens is often the preferred alternative. However, this solution will substantially increase the resistance to airflow and thus decrease cavity ventilation.

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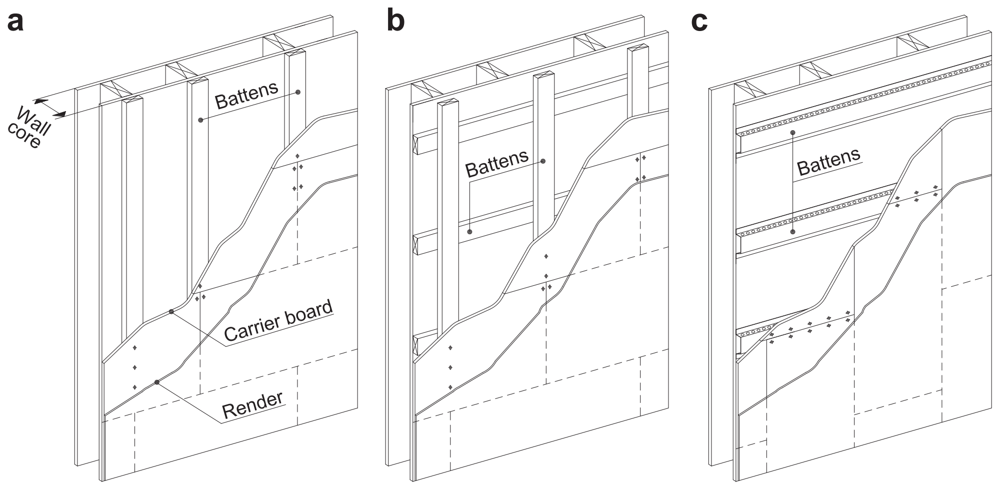

Fig. 1. Three alternative systems to create a cavity between the cladding and the wall core.

In Sweden, the major economic and social consequences in the wake of the failures with ETICS have raised doubts regarding the moisture safety of exterior walls with modern rendering systems. These concerns also include rendered rainscreen cladding systems. At the same time, national requirements have been clarified and revised in recent years and now explicitly demand that moisture safety issues in the building process should be systematically quantified and documented, both in the design- and in the construction phase. The consultants involved in the design phase often use advanced computer software to determine if the moisture performance of a building component will meet the requirements. Along with the new and ever expanding possibilities these type of programs offer, there is an increasing need of relevant input to use in the calculations.

In the case of ventilated rainscreen walls, analysis of the moisture performance requires knowledge about the cavity air change rate per hour (ACH). Furthermore, the ACH may be of substantial importance for the assessment of deformations and stresses in the cladding resulting from changes in temperature and moisture content. In reality, ventilation varies greatly depending on the specific cavity and cladding design (overall dimension, size and geometry of cavity openings, batten configuration, façade colour etc.) and the specific outdoor conditions (surrounding topography and buildings, climate etc.). This vast array of influencing factors means that ACH in wall cavities is very difficult to estimate. From a building physics perspective, there are two crucial consequences of an unknown ACH.

(1) It is difficult to compare the ability of different cavity designs to assist in the drying out process if water has been absorbed by material layers in the wall.
(2) A substantial uncertainty is introduced when computer-based, hygrothermal models are used to simulate heat and moisture conditions in walls with ventilated cavities as this type of tools relies on input from the designer regarding ACH.

Historically, rainscreen cavity ventilation and ventilation drying has been the object for numerous investigations, carried out as field studies, laboratory studies or theoretical works. Literature reviews of research findings until the middle of the 2000s are presented in reference [4–6]. Recent research includes modelling of convective drying [7], CFD simulation of wind-induced airflow [8] and analytical models for airflow rates in wall cavities [9].

The first objective of this study was to compare size and temporal variability of ACH in experimental wall cavities with different batten configurations. The second objective was to evaluate the driving forces from wind and thermal buoyancy. From a general point of view, an understanding of the action of these forces is essential to be able to make reasonably good estimations of ACH in wall cavities. Furthermore, ventilation drying capacity will be very dependent on temperature conditions in the cavity. Thus, the accuracy in calculations of drying processes will increase if the cause of the cavity airflow, wind or thermal buoyancy, is known.

Experimental walls were arranged in a test house in the south of Sweden. Long-term measurements of air velocities in the cavities were performed with a hot wire sensor. The measurements also included corresponding exterior climate (temperature, wind speed, wind direction) and temperature conditions in the cavity air. Interpretation and evaluation of the experimental data were done with a cavity airflow model.

2. Physical cavity airflow model

The objective here is to formulate the relationship between the pressure differential and the resulting airflow for a cavity with openings that are continuous along the cavity at both the top and the bottom. The top opening is covered by a metal flashing that forces the airflow to bend when leaving or entering the cavity. This flashing may also cause reduction of the flow area compared with the nominal cavity area. At the bottom, the opening is free or screened by a vented plastic profile intended to prevent intrusion of birds, bugs or rodents and to enhance aesthetics. The batten configuration is either according to Fig. 1a or 1c.

Other works [10–12] have shown that flow characteristics of wall cavities can be modelled by applying established equations from fluid mechanics. Friction loss is given by the Darcy–Weisbach friction formula while local pressure losses can be handled using the concept of local loss factors. The forces driving airflow will at steady-state be balanced by the pressure drop from friction and the local pressure drops along the flow path:

$$\Delta p_{driv} = \lambda \cdot \frac{h}{d_H} \cdot \frac{\rho_a \cdot u_m^2}{2} + \sum_{i=1}^{k} \xi_i \cdot \frac{\rho_a \cdot u_{m,i}^2}{2} \tag{1}$$

where u_m is the average air velocity in the cavity cross section. The second part of Eq. (1) is the sum of all pressure losses due to obstacles (e.g. vented battens), sudden changes in the flow area and sudden changes in the flow direction. Each of these pressure losses